NETWORK PERFORMANCE ANALYSIS

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MULTIRAD NETWORK

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MULTIRAD Network Performance Evaluation Plan During F-15 Training Utility Evaluation (TRUE)

1.0 Introduction & Background

Armstrong Laboratory's Multiship Research and Development (MULTIRAD) program is an effort to design, develop and test a low-cost, flexible multiplayer simulation system with a great degree of training utility. The MULTIRAD system is based on distributed, low cost, microprocessor based simulation including local and long haul networks.

Armstrong Laboratory's MULTIRAD development will integrate aircrew training simulators with a combat environment and exercise control functions on an asynchronous network based upon the SIMNET version 6.6 protocol with extensions.

The F-15 Training Requirements Utility Evaluation (TRUE) is a test of the training potential of the MULTIRAD system. As part of the F-15 TRUE, the MULTIRAD network will be monitored and its performance evaluated.

For TRUE the local area network (LAN) will incorporate:

- Two McDonnel Douglas Reconfigurable Cockpits (MDRC) configured as F-15C MSIP cockpits,
- A Ground Control Intercept (GCI) station,
- Two Combat Engagement Trainers (CET) configured as F-16Cs,
- An Automated Threat Environment Simulator (ATES),
- An Exercise Control Station
- A Data Logger

For the long haul portion of TRUE, the network will be connected to the Institute for Defense Analysis (IDA) facility in Alexandria, Virginia where an F-15 Combat Tactics Trainer (CTT) and GCI station will be added to the network.

Figure 1 is a block Diagram for the proposed F-15 TRUE Network.

2.0 Objectives of the F-15 TRUE Network Evaluation Plan

The purpose of this study plan is to document the F-15 TRUE Network Performance Evaluation Plan. This plan has the following objectives:

a). Perform real-time monitoring of network traffic
b). Identify packet type, source of packet, and destination of packet
c). Analyze the data contained within packets
d). Analyze the network loading characteristics
e). Perform comparison of multiple packets
f). Generate packets for the purpose of determining protocol compliance

3.0 Overview of TRUE

3.1 General

The Network Performance Evaluation will occur in conjunction with TRUE testing. TRUE is structured around simulated, combat oriented, training missions for F-15 pilots and Air Weapons Controllers. The TRUE will consist of three sets of tests with increasing numbers of players and simulation complexity.

The test scenarios are:

a). [1 vs 1]
- one F-15 vs one-
- F-15 or
- CET or
- AIT or
- digitally controlled aircraft or
- digitally controlled surface threat

This test will focus on component fidelity rather than training effectiveness

b). [2 vs "x" (Local)] - Two F-15s vs many enemy aircraft including CET's, AIT, digitally controlled aircraft and digitally controlled surface threat

c). [2 vs "x" (Long haul)] - Two F-15's vs many enemy aircraft with players located at IDA.

3.2 Target Dates

a). Complete 1 vs 1 preliminary evaluations - TBD
b). Conduct 1 vs 1 evaluation by F-15E pilots - TBD
c). Complete 2 vs "x" (local) preliminary evaluations - TBD
d). Conduct 2 vs "x" (local) scenarios using two F-15E pilots - TBD
e). Conduct 2 vs "x" (long haul) scenarios using two F-15C pilots plus one controller at Brooks AFB and 2 F16 AIT pilots at Luke AFB - TBD

f). Conduct TRUE for 2 vs "x" (local) scenarios using 16 F-15C pilots plus 8 AWCs - TBD

g). Conduct TRUE for 2 vs "x" (long haul) scenarios using 16 F-15C pilots plus 8 AWCs - TBD

h). Draft Report on TRUE network evaluation - TBD

i). Final report on TRUE network evaluation - 15 DEC 92

4.0 TRUE Performance - Data Collection and Analysis Procedure

4.1 Protocol Compliance

Prior to execution of the full TRUE network evaluation, it will be necessary to verify the extensions to existing Protocol Data Units (PDU) and new PDU-types generated under the MULTIRAD contract.

The extensions to existing PDUs are:

- Activate Request
  - Mission Number
  - Initial Speed
  - Initial freeze state
  - Fuel quantity
  - Radio channel
- Deactivate Request
  - Time Stamp
- Vehicle Appearance
  - Fuel quantity
  - Throttle position
  - Linear acceleration vector
  - Angular velocity vector
- Fire
  - Time Stamp
- Impact
  - Time Stamp

New PDUs are:

- Radar
- Emitter
- Freeze

The protocol extensions and new PDUs format will be verified by stepping a simulator through maneuvers or activating controls that generate the specific PDUs and then capturing and analyzing the network traffic using the data logger.

4.2 Network Evaluation

During execution of the actual TRUE exercises i.e. 1 vs 1, 2 vs "x" (local) and 2 vs "x" (long haul) the network performance will be recorded and/or analyzed using the following equipment:

- Data logger/SUN Workstation - packet by packet record of events
- Network analyzer - Network loading and performance statistics
- NIU network data and queue analysis

4.2.1 Data Logger/SUN Workstation

The network PDU traffic for each exercise will be recorded by a data logger or SUN Workstation equipped with dual tape drives.

The data logger time-stamps the packets as it receives them from the network and writes them to the tape. This provides a permanent record of events. After the exercise is run, the data tapes can be either replayed over the network or analyzed. Play back is visible to any device on the network (i.e. Exercise control Station and simulators).

The data logger, when set-up in the continuous record mode can "ping pong" between its dual tape drives - automatically switching to the next drive when the first one is full. A single 2400 foot tape at 1600 bpi will record between one and ten minutes of real time events at a network data rate of 800,000 bps (the maximum expected) or 80,000 bps respectively. The network data rate for each exercise will determine whether or not the entire exercise is recorded.

Analysis programs for the data tapes are being written. By analyzing the tapes off-line, the following things can be determined:

- packet latency
- # of corrupt packets
- frequency and average number of out-of-order packets

4.2.1.1 Packet Latency

Maximum and average packet latency is determined by comparing the time stamp generated at packet creation with the time stamp generated by the data logger at packet receipt. The latency determined here will represent the cumulative delay caused by waiting in the NIU output queue for access to the ethernet and transmission on the ethernet.

Of even greater interest than average packet latency is the amount of jitter or variance that the network experiences from packet to packet. A constant delay for a packets arrival may not be noticeable whereas a variable delay may cause unacceptable performance degradation. As part of the post analysis, latency jitter will be measured and reviewed.

4.2.1.2 Packet Corruption

The contents of a packet may be corrupted during transmission. Packet corruption is determined by looking at the data fields within a PDU to determine if all values are within the limits prescribed by the Simnet protocol.

4.2.1.3 Out-of-order Packets

Out-of-order packets can occur on the network when a data gram sent first is overtaken by one sent second because it encounters a larger delay. By comparing the originating time stamps on each PDU, statistics for out-of-order packets from individual sources and the global network can be determined.

4.2.2 Network Analyzer

The network analyzer at Armstrong Labs that is piggy backed on a Compaq computer can be programmed to display and record instantaneous and averaged network loading information such as bandwidth utilization, average packet size, packet type frequency of occurrence and network anomalies such as collisions.

4.2.3 NIU Data Collection

Each NIU will need to run background programs to generate performance statistics as part of their normal functioning. These statistics will indicate how much idle time and NIU has and how big the input and output PDU queues are on average and instantaneously. Each NIU will also need to monitor the frequency of time late data both globally and for each single source. The background programs needed to capture this data and generate statistics do not yet exist and must be written.

4.3 Time Synchronization

In order to accurately time stamp each PDU, it is recommended that NIU's be synchronized once a day with WWV. WWV is a radio station operated by the National Bureau of Standards (NBS) that broadcasts Coordinated Universal Timer signals. WWV is located near Fort Collins, Colorado. The time and frequency broadcasts are controlled by the NBS Frequency Standard (a cesium atomic standard). The frequencies transmitted by WWV are held stable to better than 2 part in 1000 billion at all times.

Several products are available that receive the WWV broadcast and output an RS-232 synchronization signal. The RS-232 signal would then be tied to each NIU at a site. For the long haul portion of the testing, IDA and Williams AFB would both require a receiver for synchronization. The synchronization accuracy achievable by using WWV broadcasts would be within approximately 2030 milliseconds for a long haul network to IDA. An alternate method of synchronizing the NIU's using WWV is with a dial-up system that automatically measures the round-trip propagation delay on the telephone and compensates for it. This method has a clock accuracy of 10 milliseconds. A third synchronization method would be to broadcast the freeze command over the net from a single NIU. This method would produce a synchronization accuracy of approximately 50 - 100 milliseconds or twice the total net propagation delay, which ever is greater.

5.0 Content of Final Report

The final report for TRUE Network Evaluation will contain:

a). Brief description of the simulation system networks
b). Description of the mission scenarios
c). Description of any special test equipment
d). Summary of network performance including:
 - Peak network loading
 - Average network loading
 - Average packet size

- Frequency of occurrence of packet type
- # of network message collisions detected
- Frequency of network message collisions
- Frequency and average number of out-of-order packets

e). Analysis of network loading including:

- Individual NIU loading
- Maximum NIU queue size
- Average NIU queue size
- Maximum message latency
- Average message latency
- Analysis of packet contents
- Packet protocol compliance

f). Overall assessment of network performance for local and long haul scenario's

g). Recommendations for future network improvements and developments